N87-20666

SATELLITE LIFETIME PREDICTION

Gerald Wittenstein, NASA/Marshall Space Flight Center

Satellite lifetime predictions are critically dependent on the ability to forecast future solar and geomagnetic activity. These quantities are inputs to the atmospheric model with which values of atmospheric density are computed along a projected orbital path. Density values are combined with the predicted ballistic coefficient timeline to compute drag and predict decay histories. The major uncertainty in making predictions that pertain to time periods that are years in the future is in the solar and geomagnetic activity projections, although the ballistic coefficient is also frequently in doubt.

Reliable lifetime predictions are of great importance. Lifetime in terms of years of on-station operation and reboost requirements are major drivers of system costs. For the space station a major issue is to predict when reboost is necessary. For low solar activity (sunspot number 50) it is estimated that 1000 lb of propellant are required for reboost each year, while for high activity (sunspot number 200) 10,000 lb are required.

Comparisons between actual and predicted orbit lifetimes show large differences that are due mostly to the uncertainties in predicting solar/geomagnetic activity. When the actual solar/geomagnetic indices that were observed during the orbital lifetime are put into the models during post-flight orbital analyses, the models work quite well, within about 10 - 15 percent in lifetime. High inclination orbits may be expected to exhibit the greatest variability (Roble).

Given present knowledge, solar cycle uncertainties are unavoidable. A reasonable procedure is to go with the best forecasts available, and try to allow for variations by estimating lifetimes for both nominal and plus two-sigma solar activity levels. Short term variations are essentially unpredictable.

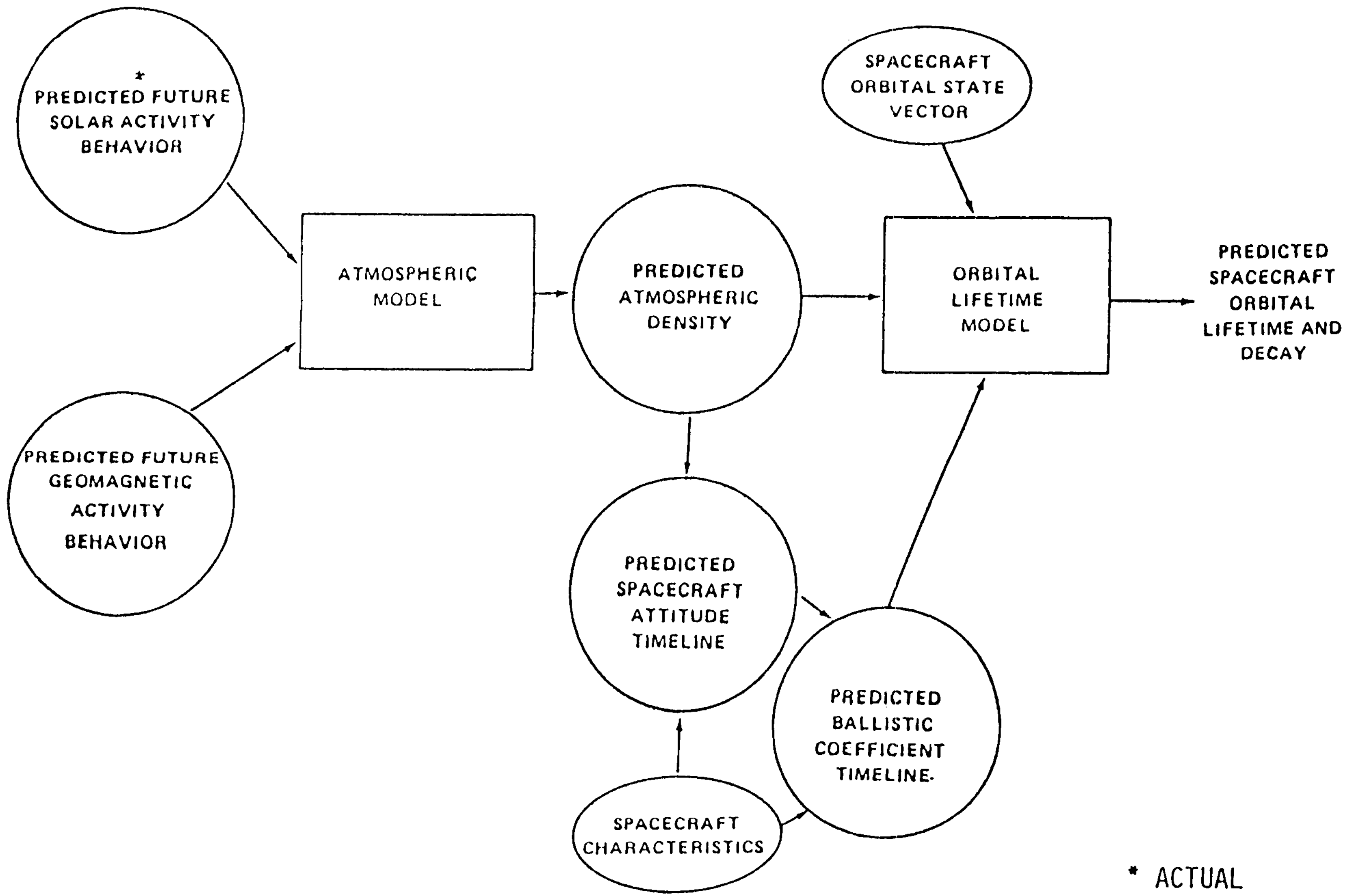
USER SUMMARY Satellite lifetime

In summary, while present density models are adequate for planning, the inputs to them, particularly solar/geomagnetic activity indices, are unreliable.

ORGANIZATION: EL25	MARSHALL SPACE FLIGHT CENTER	NAME: G. WITTENSTEIN
CHART NO.:	SATELLITE LIFETIME	DATE: NOVEMBER 18, 1985

- oo INTRODUCTION
- oo DESIGN PROBLEMS CONCERNING SATELLITE LIFETIME
- oo THE UNAVOIDABLE - EFFECT OF SOLAR CYCLE UNCERTAINTIES
- oo MISSION PLANNING EFFECTS
- oo SUMMARY

SOLAR PREDICTIONS AND SPACECRAFT ORBITAL LIFETIME



* ACTUAL

NASA/MSFC/ES-81

ORGANIZATION: EL25	MARSHALL SPACE FLIGHT CENTER	NAME: G. WITTENSTEIN
CHART NO.:	SATELLITE LIFETIME	DATE: NOVEMBER 18, 1985

00 DESIGN PROBLEMS CONCERNING SATELLITE LIFETIME

- 0 SYSTEM COST - $ vs YEARS OF OPERATION, REBOOST
- 0 SATELLITE CONTROL SYSTEM DESIGN, SPACE TELESCOPE, SKYLAB, SPACE STATION
- 0 ORBIT ALT MAINTENANCE - REBOOST/ORBIT TRIM SYSTEM - SPACE STATION
- 0 SATELLITE MATERIAL DETERIORATION - O (ATOMIC OXYGEN) - ALL

ORGANIZATION: EL25	MARSHALL SPACE FLIGHT CENTER	NAME: G. WITTENSTEIN
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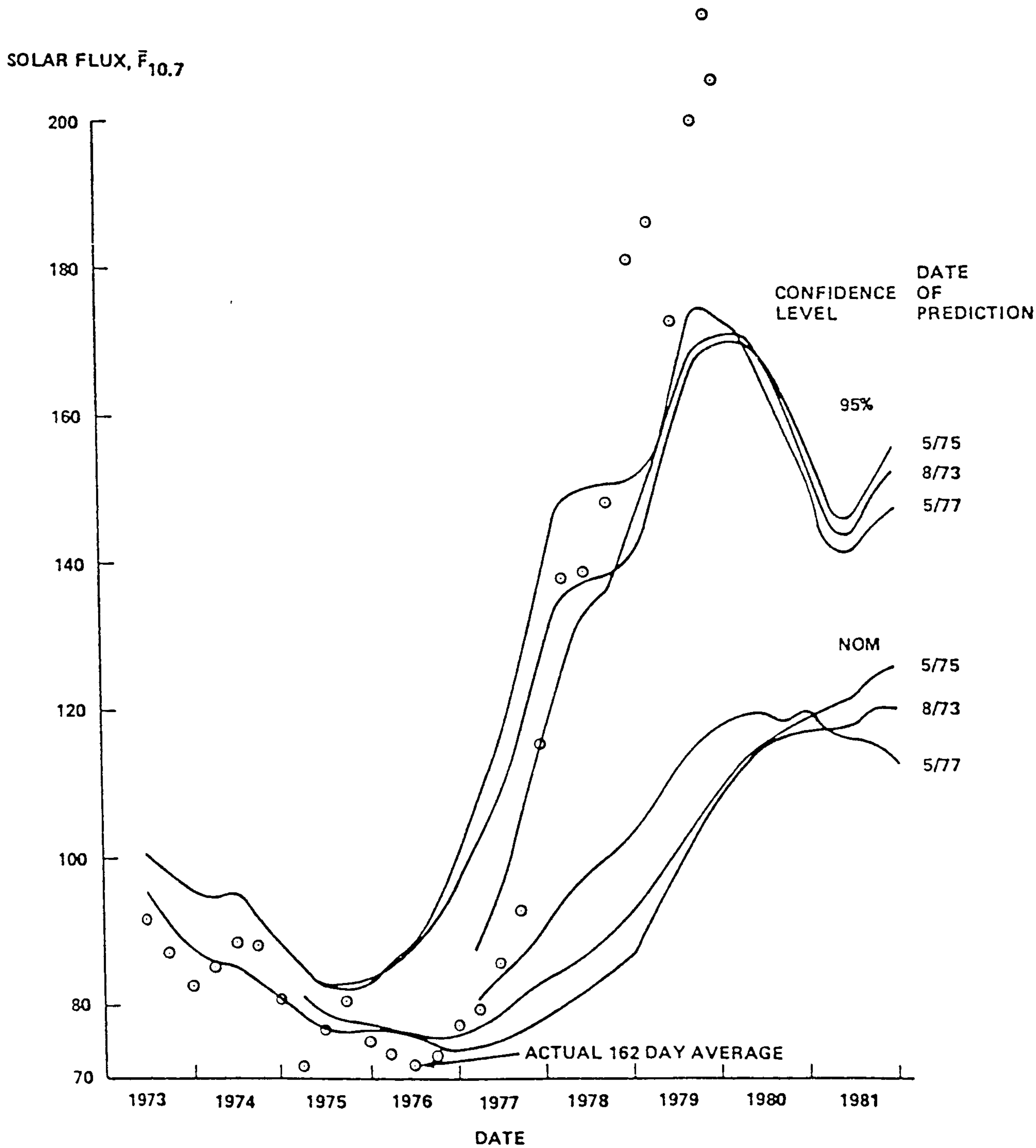
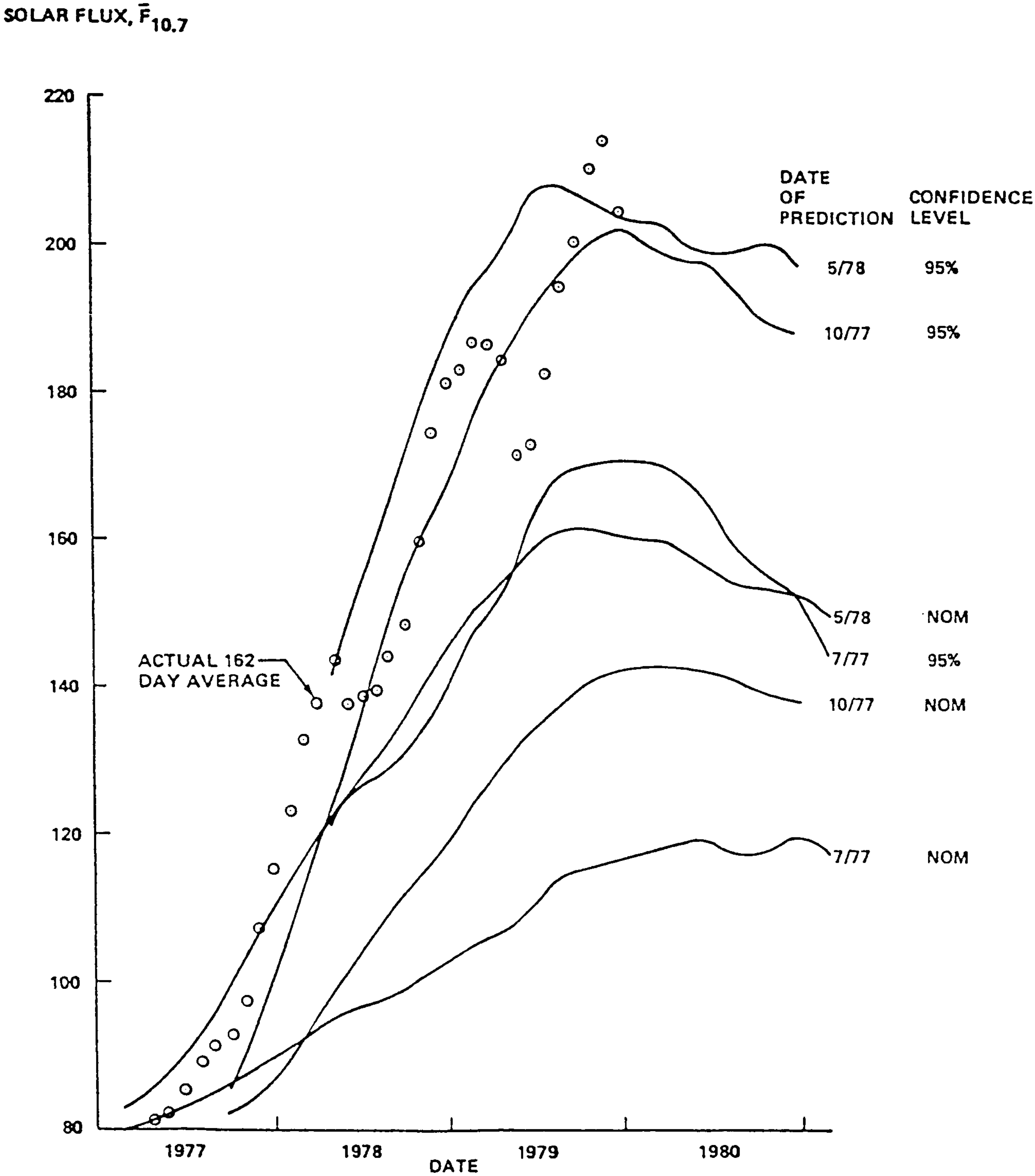
00 THE UNAVOIDABLE - EFFECT OF UNCERTAINTIES IN PREDICTING SOLAR ACTIVITY

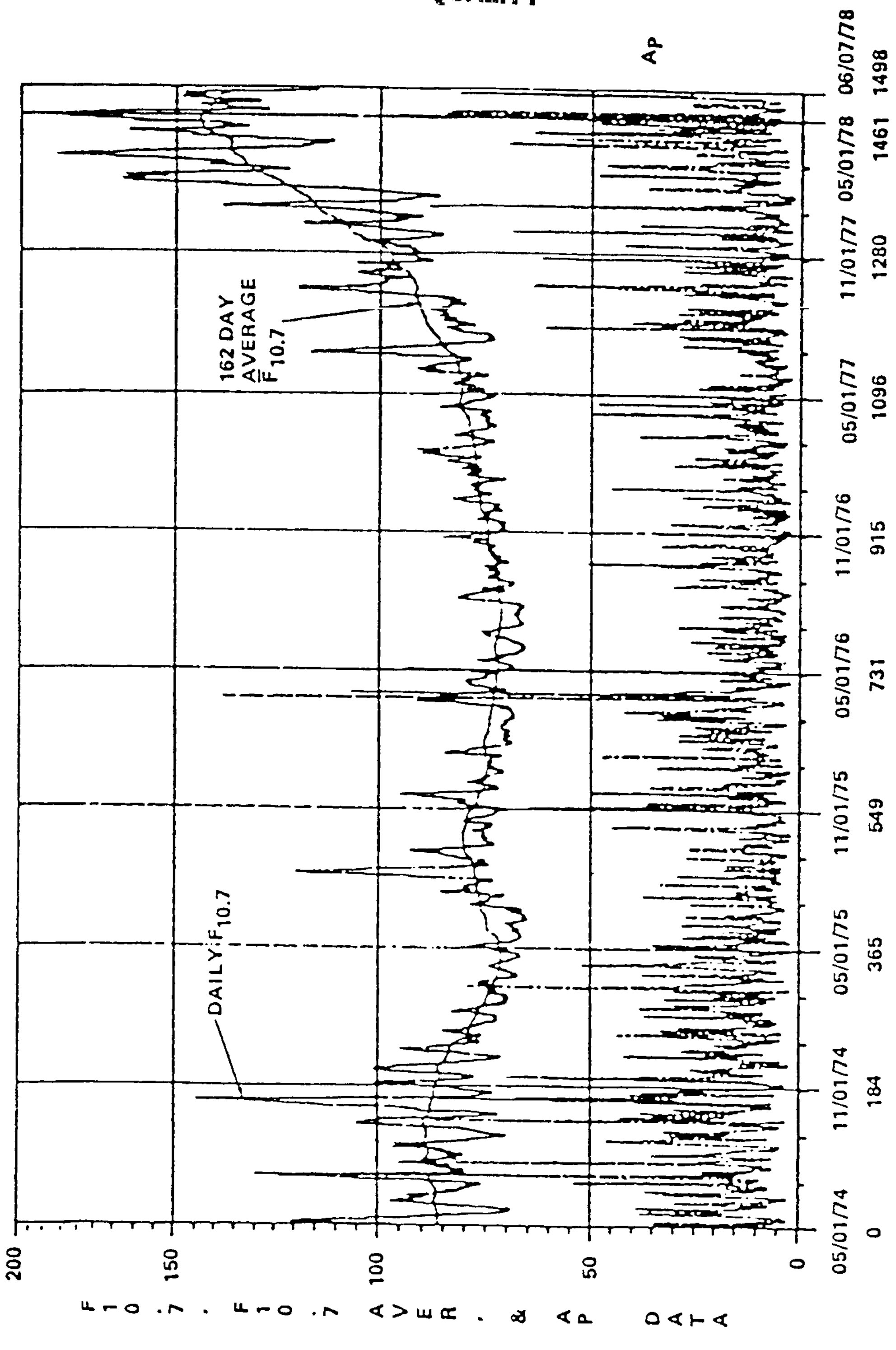
- 0 SOME POLITICAL/PROGRAMMATIC EFFECTS - $, TIME, vs IMPACT ON GO AHEAD IF PROJECT WON'T SUCCEED WITH A CERTAIN PROBABILITY
- 0 NOMINAL AND $\pm 2\sigma$ ATMOS. VARIATIONS - WHEN AND HOW BIG
- 0 DAILY VARIATIONS - SPIKES IN ρ, AP, F 10.7



ACTUAL AND PREDICTED SOLAR FLUX



ACTUAL AND PREDICTED SOLAR FLUX



ACTUAL SOLAR ACTIVITY DATA

ORGANIZATION: EL25	MARSHALL SPACE FLIGHT CENTER	NAME: G. WITTENSTEIN
CHART NO.:	SATELLITE LIFETIME	DATE: NOVEMBER 18, 1985

00 MISSION PLANNING EFFECTS

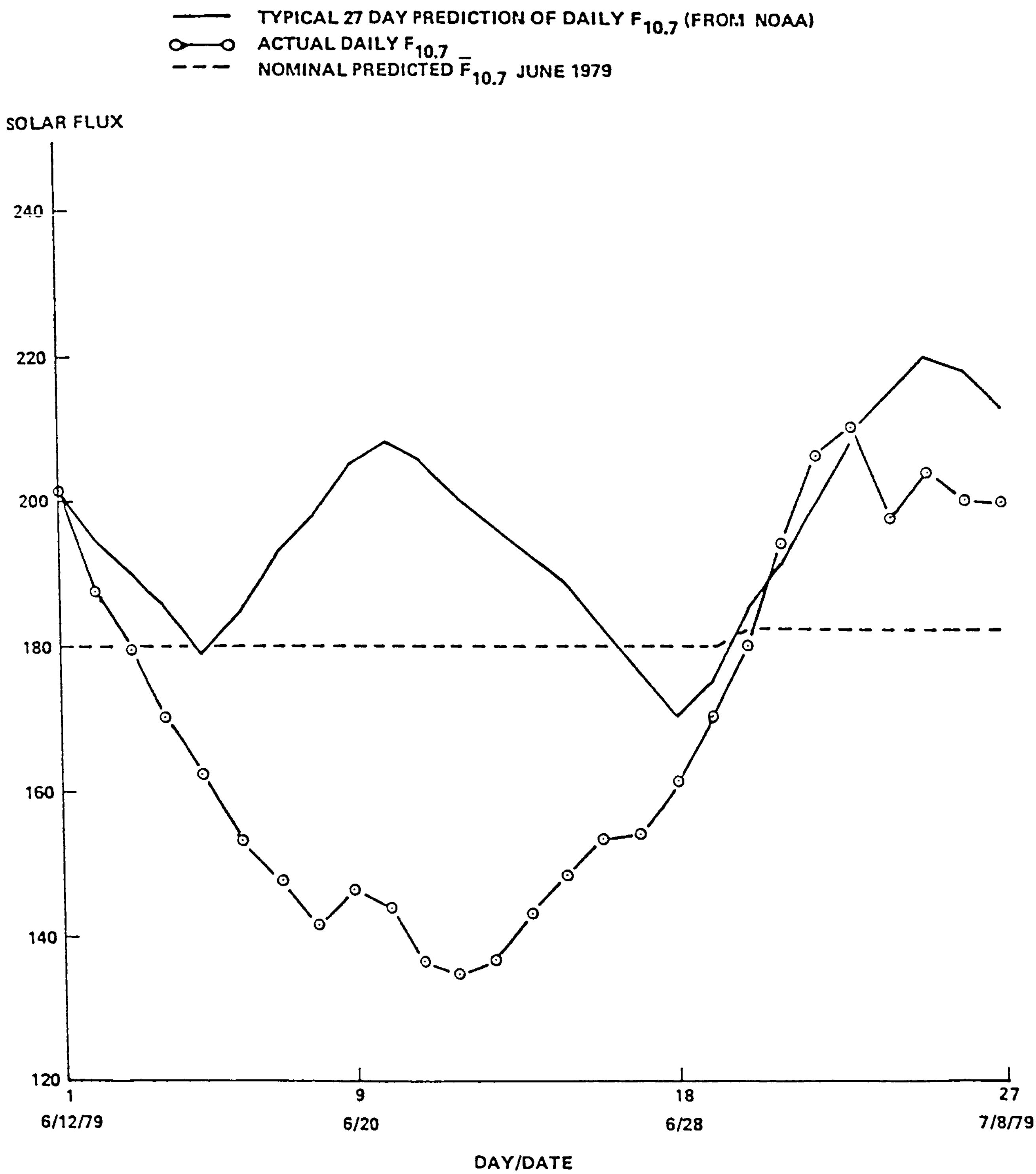
- 0 SKYLAB - SOME INTERESTING NOTES ON LIFETIME
    - 0 SOLAR ACTIVITY - PREDICTIONS - ACTUAL
    - 0 TIMELAGS, BIASES AND FUDGE FACTORS
    - 0 SPACE TELESCOPE AND REACTION WHEEL ASSEMBLY DESIGN - SPIKE IN P, AP ... WHAT TO DO.
    - 0 SPACE STATION - ORBIT MAINT. ORBIT DECAY PREDICTION AND FREQUENCY TO UPDATE

MISSION DESCRIPTION FOR CLUSTER CONFIGURATION AND LIFETIME PREDICTION (SKYLAB)

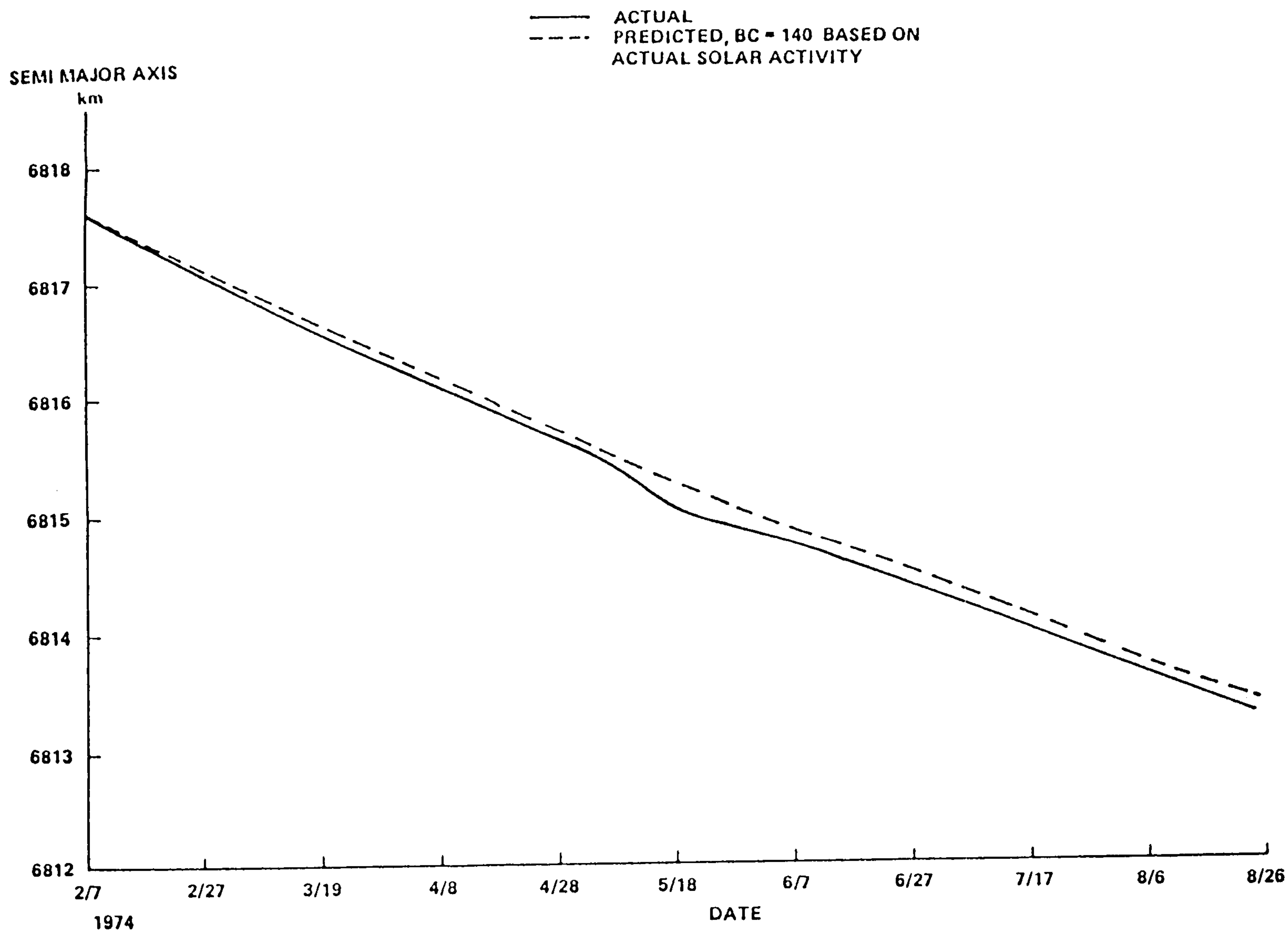
Memorandum Date		9/20/69 (MSFC)		1/20/70 (MSFC)		4/70 (LMSC)		12/2/70 (MSFC)		9/6/72 (MSFC)	
		Time	M/C_DA	Time	M/C_DA	Time	M/C_DA	Time	M/C_DA	Time	M/C_DA
Phase	Configuration	(Days)	(kg/m^2)	(Days)	(kg/m^2)	(Days)	(kg/m^2)	(Days)	(kg/m^2)	(Days)	(kg/m^2)
1	WS	0-2	89.33	0-2	101.6	0-2	115.24	0-1	115.24	Initial	
2	WS + CSM	2-30	106.42	2-29	115.2	2-30	128.83	1-29	128.83	Altitude	
3	WS	30-90	87.10	29-85	99.3	30-90	114.16	29-71	114.16	Maintained	
4	WS + CSM	90-146	103.18	85-140	111.5	90-146	127.84	71-127	127.84	Until End of	
5	WS	146-180	82.32	140-190	95.0	146-180	112.64	127-173	112.64	Manned	
6	WS + CSM	180-236	98.84	190-245	107.4	180-236	126.83	173-229	126.38	Mission	
7	WS	236-Impact	77.64	245-Impact	90.6	236-Impact	111.56	229-Impact	111.56	240-Impact	122.0
Launch Date		3/15/72		3/15/72		7/15/72	11/15/72	11/9/72		4/30/73	
Altitude (nmi)		235		235		235	235	235		235	
Inclination (deg)		35		50		50	50	50		50	
Mass (kg) at end of mission		44826		52317		67962	67962	67962		74558	
Predicted Lifetime Nominal - Days		1660		1760		2093	2070	2074		2360	
Years		4.54		4.82		5.73	5.67	5.68		6.64	
$+2\sigma$ - Days		1120		1210		1442	1394	1415		1650	
- Years		3.07		3.32		3.95	3.82	3.87		4.52	

SKYLAB LIFETIME (IMPACT) PREDICTIONS
DURING THE PASSIVE PERIOD

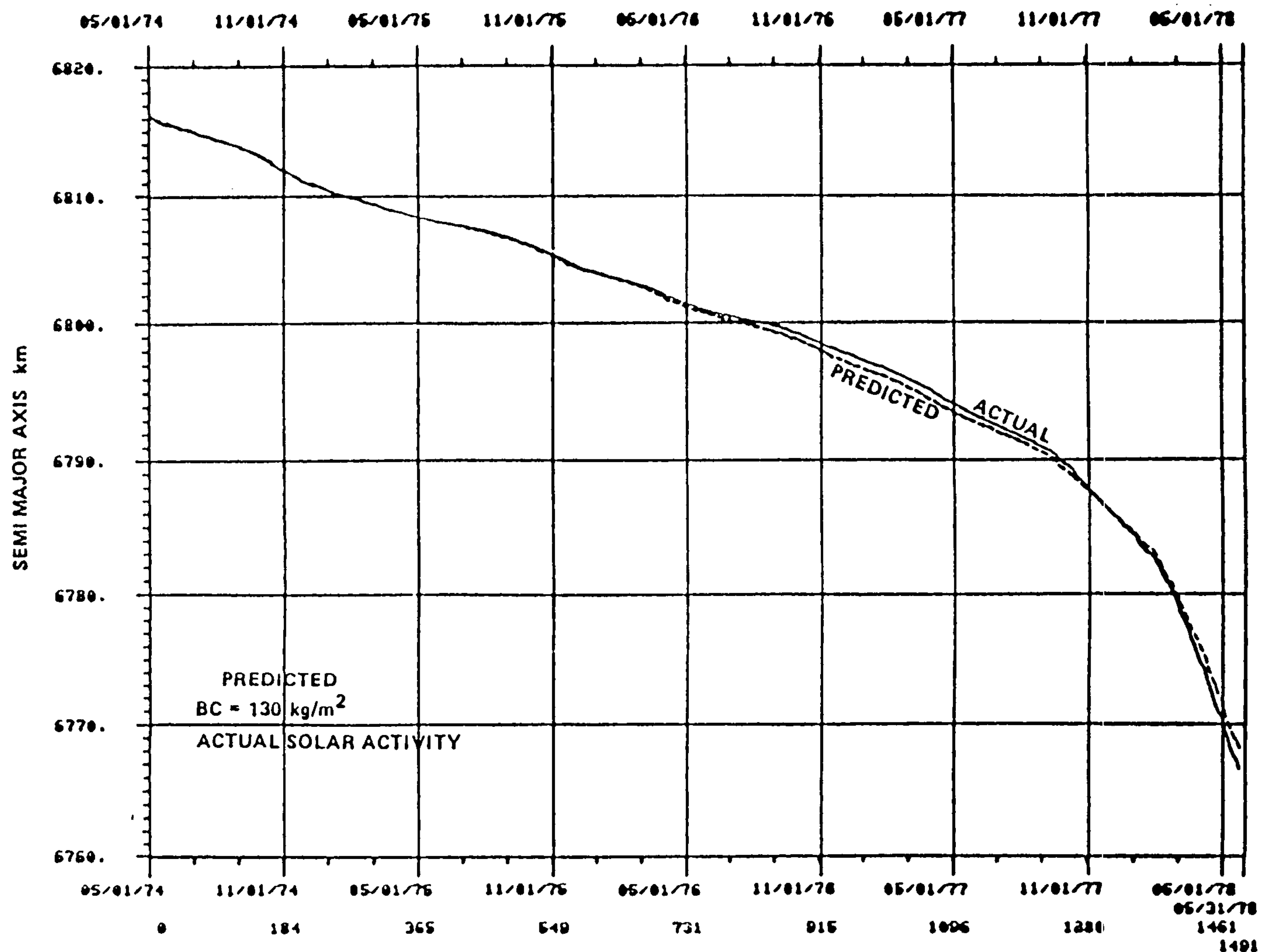
Memo Date	Ballistic Coefficient (kg/m^2)	Predicted Impact (Mo/Yr or Mo/Day/Yr)		
		Nominal	$+2\sigma$	-2σ
Aug. 1, 1973	170	7/81	9/78	10/85
Mar. 11, 1974	207	3/83	11/79	6/92
Sep. 3, 1974	140	5/81	10/78	10/84
Nov. 27, 1974	140	4/81	10/78	6/84
Dec. 12, 1974	140	4/81	10/78	6/84
Feb. 20, 1975	120	1/81	9/78	1/83
May 20, 1975	120	12/80	9/78	11/82
Jul. 27, 1977	144	12/2/80	8/21/79	
Aug. 16, 1977	144	12/7/80	8/23/79	
Oct. 15, 1977	144	4/16/80	5/31/79	
Nov. 18, 1977	144	3/23/80	5/14/79	
Dec. 18, 1977	144	3/14/80	5/22/79	
Feb. 9, 1978	144	12/21/79	5/3/79	
Apr. 10, 1978	144	8/29/79	4/13/79	



COMPARISON OF PREDICTED AND ACTUAL SOLAR FLUX



ACTUAL AND PREDICTED DECAY COMPARISON



MIPS>

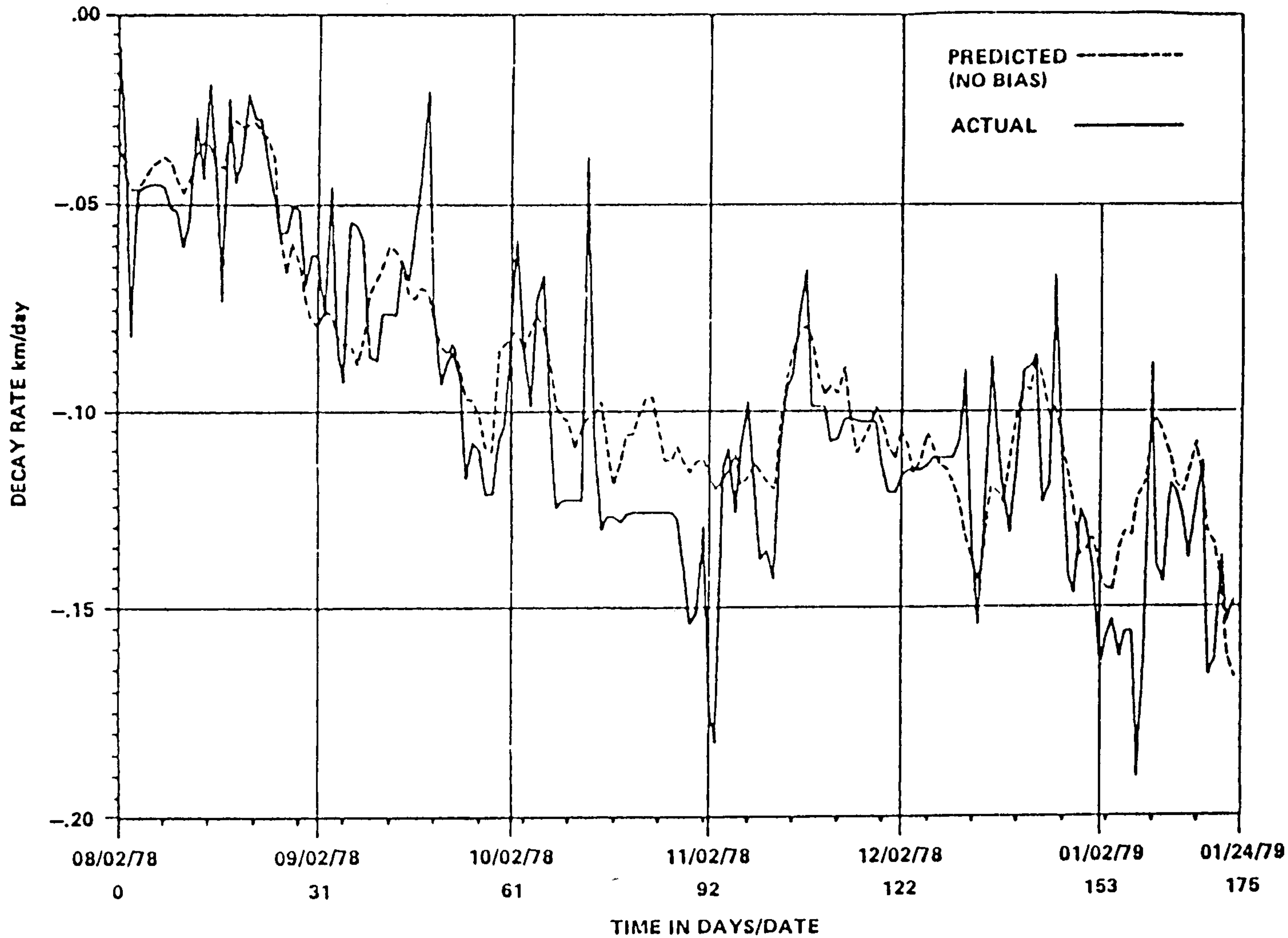
NOTE: EARTH RADIUS IS ~6378 km

PREDICTED AND ACTUAL DECAY

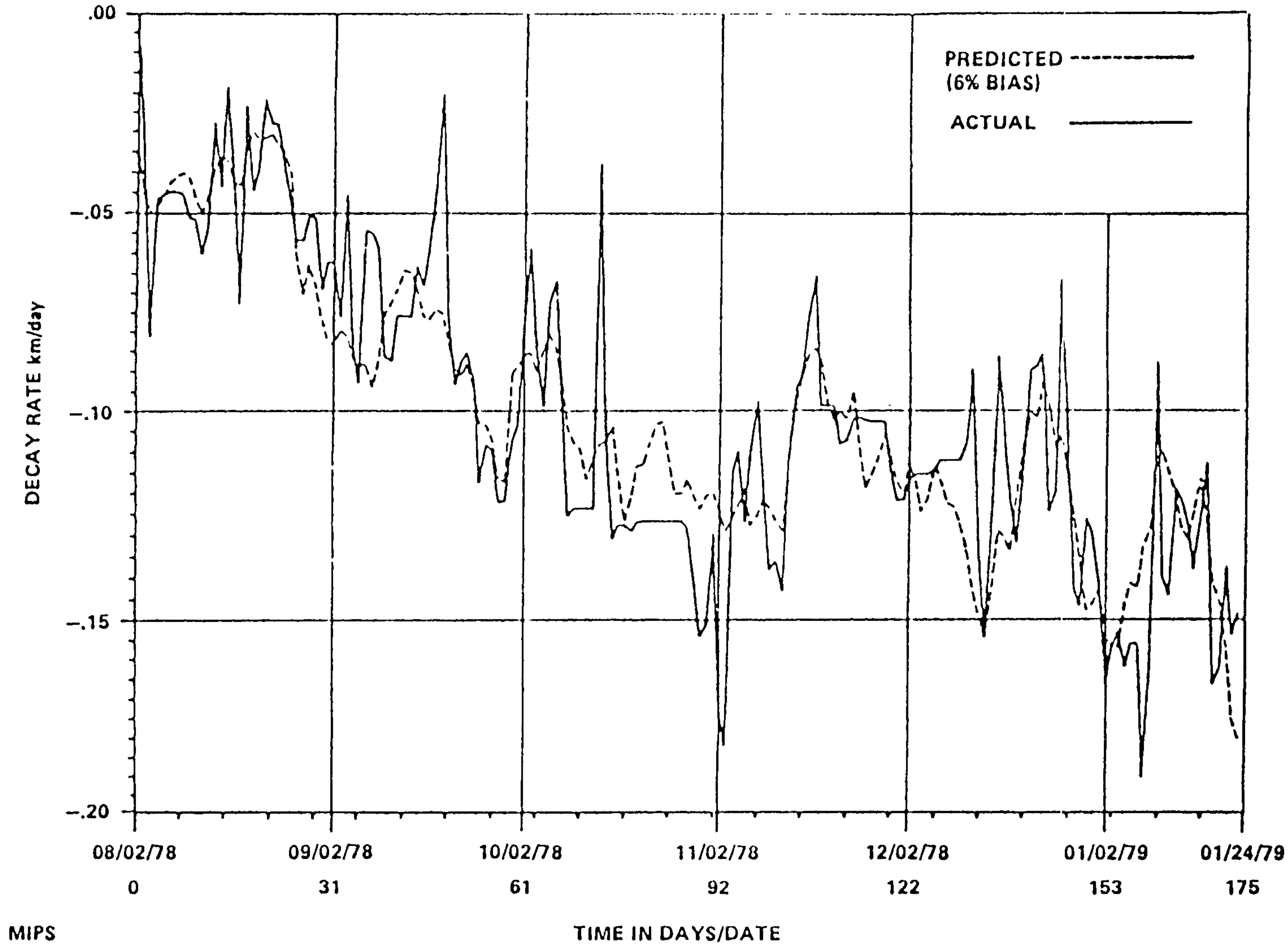
0 20 40 60 80 100 120 140 160 180

TIME IN DAYS/DATE

EOVV DECAY COMPARISON USING THEORETICAL BC



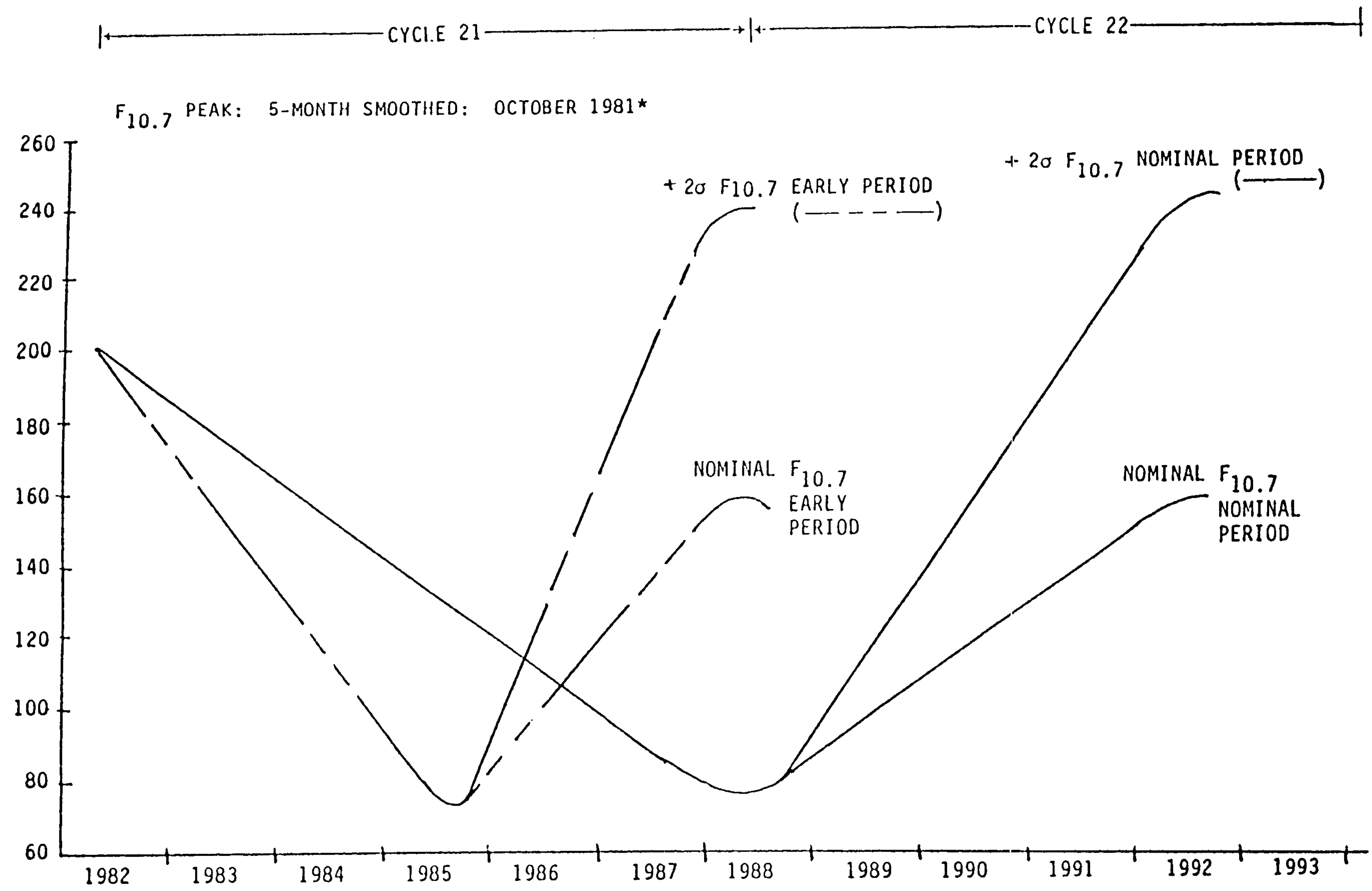
EOVV PREDICTED AND ACTUAL DECAY RATES USING THEORETICAL BC



PREDICTED AND ACTUAL DECAY RATES DURING EOVV USING THEORETICAL BC

ORGANIZATION: EL25	MARSHALL SPACE FLIGHT CENTER	NAME: G. WITTENSTEIN
CHART NO.:	STATEMENT ON BIAS IN EL25 ATMOSPHERIC MODEL	DATE: NOVEMBER 18, 1985

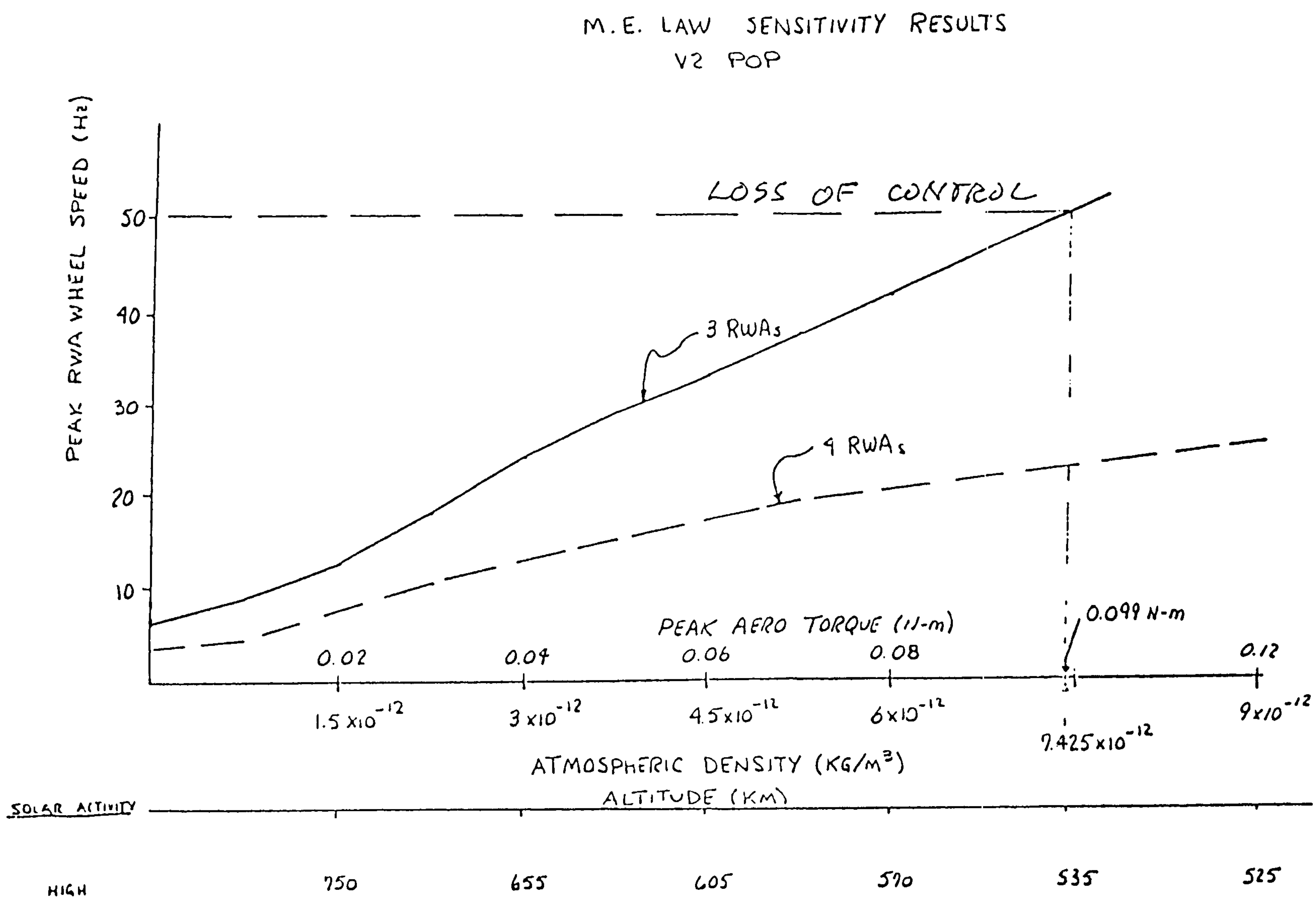
- FOR A HIGH RAPIDLY RISING SOLAR ACTIVITY BC APPEARS 5% TO 10% LOWER
- FOR A LOW STEADILY RISING SOLAR ACTIVITY BC APPEARS 5 TO 10% HIGHER



*SUNSPOT PEAK--OCCURRED IN DECEMBER 1979.

ORGANIZATION: EL25	MARSHALL SPACE FLIGHT CENTER	NAME: G. WITTENSTEIN
CHART NO.:	SPACE TELESCOPE/REACTION WHEEL ASSEMBLY DESIGN	DATE: NOVEMBER 18, 1985

- O TWO MAJOR PROBLEMS
  - O WHEEL SPEED AND CONTROL
  - O JITTER AND SCIENCE QUALITY


M.E. LAW SENSITIVITY RESULTS
V2 POP
LOSS OF CONTROL
3 RWAs
4 RWAs
PEAK RWA WHEEL SPEED (Hz)
50
40
30
20
10
PEAK AERO TORQUE (N-m)
0.02
0.04
0.06
0.08
0.099 N-m
0.12
1.5 x10^-12
3 x10^-12
4.5 x10^-12
6 x10^-12
7.425 x10^-12
9 x10^-12
ATMOSPHERIC DENSITY (KG/m^3)
ALTITUDE (KM)
SOLAR ACTIVITY
HIGH
750
655
605
570
535
525

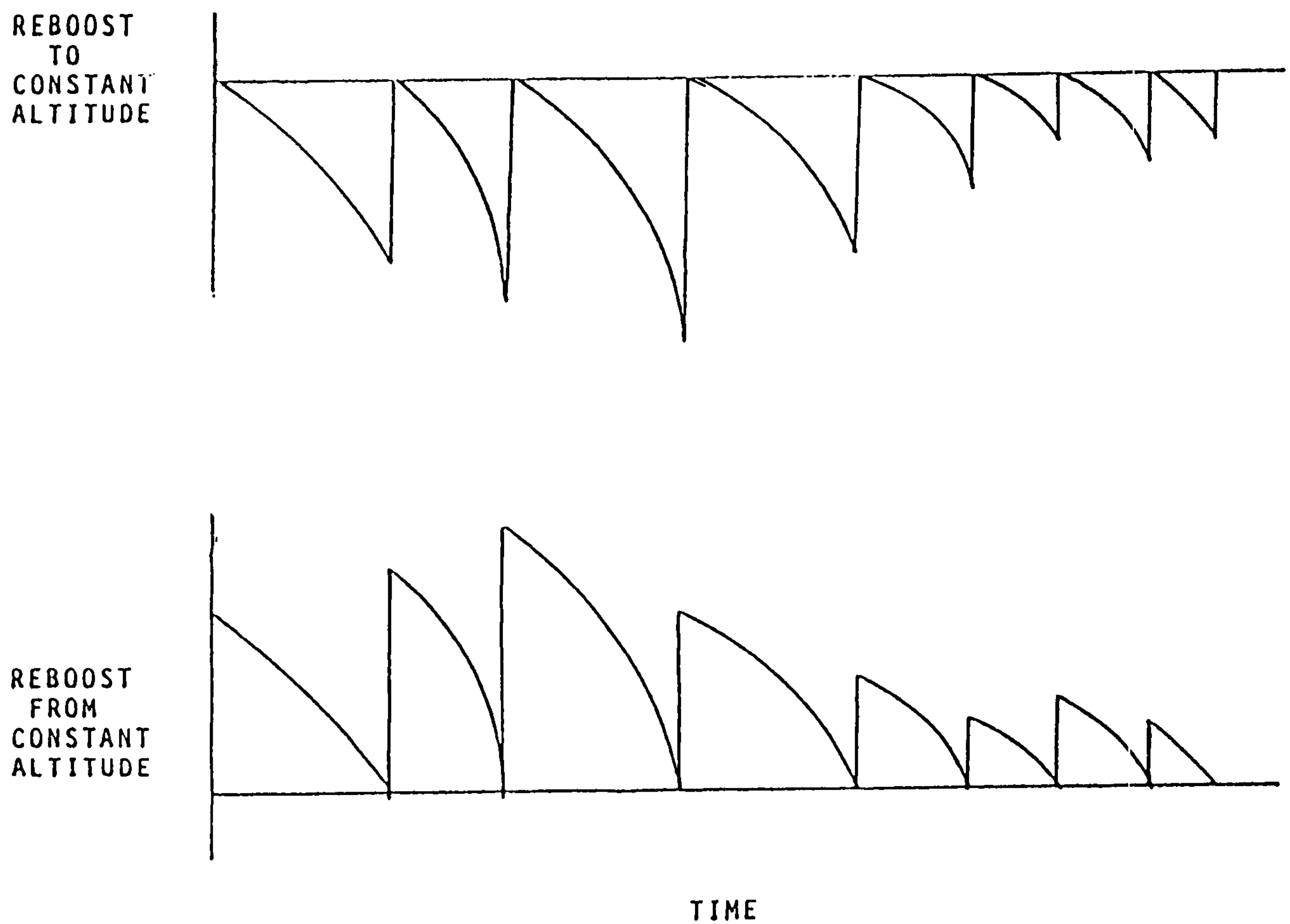
ORGANIZATION: EL25	MARSHALL SPACE FLIGHT CENTER	NAME: G. WITTENSTEIN
CHART NO.:	ORBITAL LIFETIME APPLICATIONS	DATE: NOVEMBER 18, 1985

ORBITAL LIFETIME APPLICATIONS

FOR LOW ORBIT EARTH SATELLITES SUCH AS THE PLANNED MANNED SPACE STATION REBOOST WILL BE NECESSARY TO PROVIDE THE LONG DURATION LIFETIME. THESE PERIODIC REBOOSTS COULD BE DONE WITH A PROPULSIVE VEHICLE OR THE SPACE STATION COULD HAVE ITS OWN SYSTEM FOR REBOOST. ESTIMATES HAVE BEEN MADE OF THE PROPELLENT REQUIRED FOR REBOOST FOR LEVELS OF SOLAR ACTIVITY AS SHOWN BELOW.

SOLAR ACTIVITY	SUNSPOT NUMBER	PROPELLENT REQUIRED IN POUNDS EACH YEAR
LOW	50	1,000
MEDIUM	100	3,000
HIGH	200	10,000

ORGANIZATION: EL23	MARSHALL SPACE FLIGHT CENTER	NAME: V. L. BUCKELEW
CHART NO.:	REBOOST PROFILES	DATE: AUGUST 1985



SUMMARY

SOLAR ACTIVITY EFFECT ON ATMOSPHERIC DENSITY PLAYS A MAJOR ROLE IN

- o MISSION PLANNING
- o SATELLITE/SPACECRAFT DESIGN, COST AND OPERATION
- o EXPERIMENT OPERATIONAL QUALITY
- o BAD PRESS